Deep Learning for Transverse Cirrus Band Detection and Analysis

Jeffrey Miller, Udaysankar Nair, Rahul Ramachandran, and Manil Maskey

Introduction

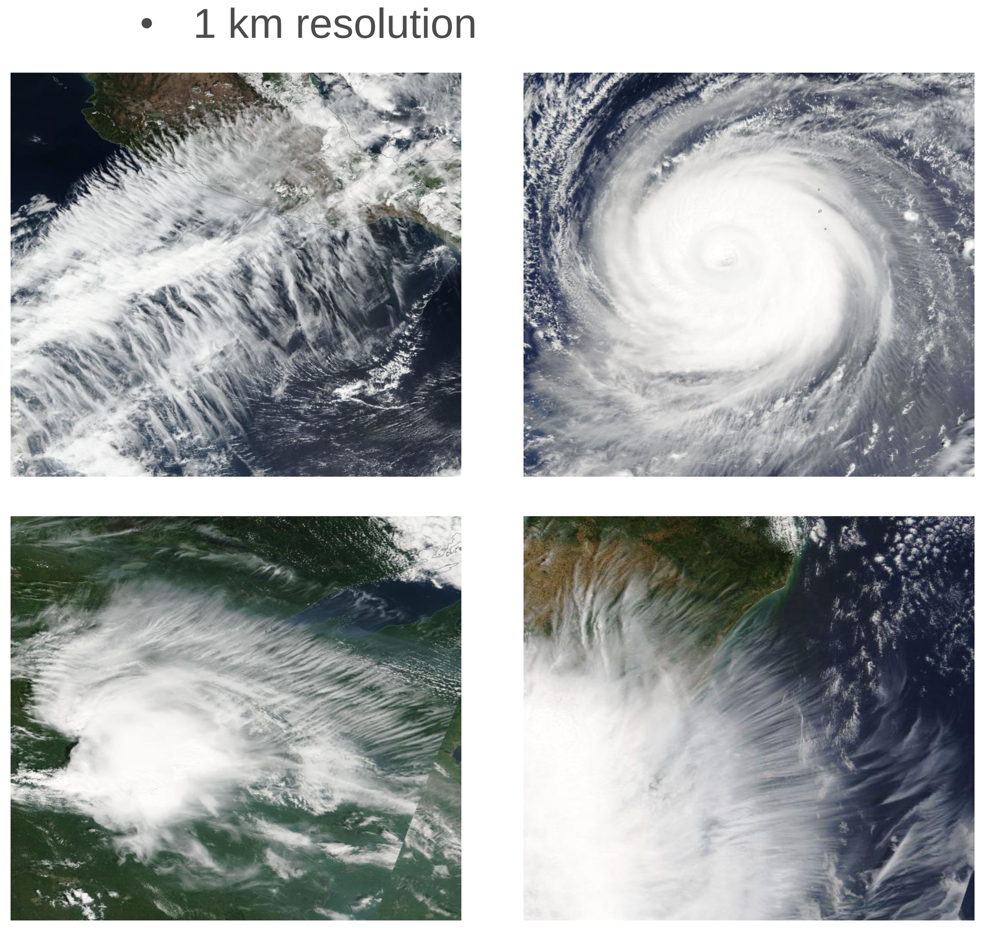
Transverse cirrus bands (TCBs) are an upper-level cloud formation that occur in conjunction with meteorological phenomena such as jet streaks (JS), tropical cyclones (TC), extratropical cyclones (ETC), and mesoscale convective systems (MCS) and are often used as a proxy for clear-air turbulence.

Research Questions

1. Can a CNN that was trained for ordinary image classification be retrained to detect transverse cirrus bands in true-color MODIS satellite imagery?
2. In which regions do TCBs most often form and do these regions change seasonally?
3. From what parent phenomena do TCBs most often form?

Data

- Training data was obtained from NASA Worldview and a pre-existing dataset [Maskey et al. 2017]
    - MODIS and VIIRS RGB true color composite
    - 5579 images
- Climatology data (2013 – 2015) was obtained from Global Imagery Browse Service (GIBS)
    - MODIS Terra RGB true color composite
    - ~250,000 tiles per year
    - 1 km resolution



Training Methodology

- VGG16 [Simonyan and Zisserman 2015]
- Class Activation Map (CAM) [Zhou et al. 2015]
    - Replaced fully-connected layers with 1 conv layer and 1 GAP layer
- Used transfer learning
    - First 12 layers were fixed (not trained)

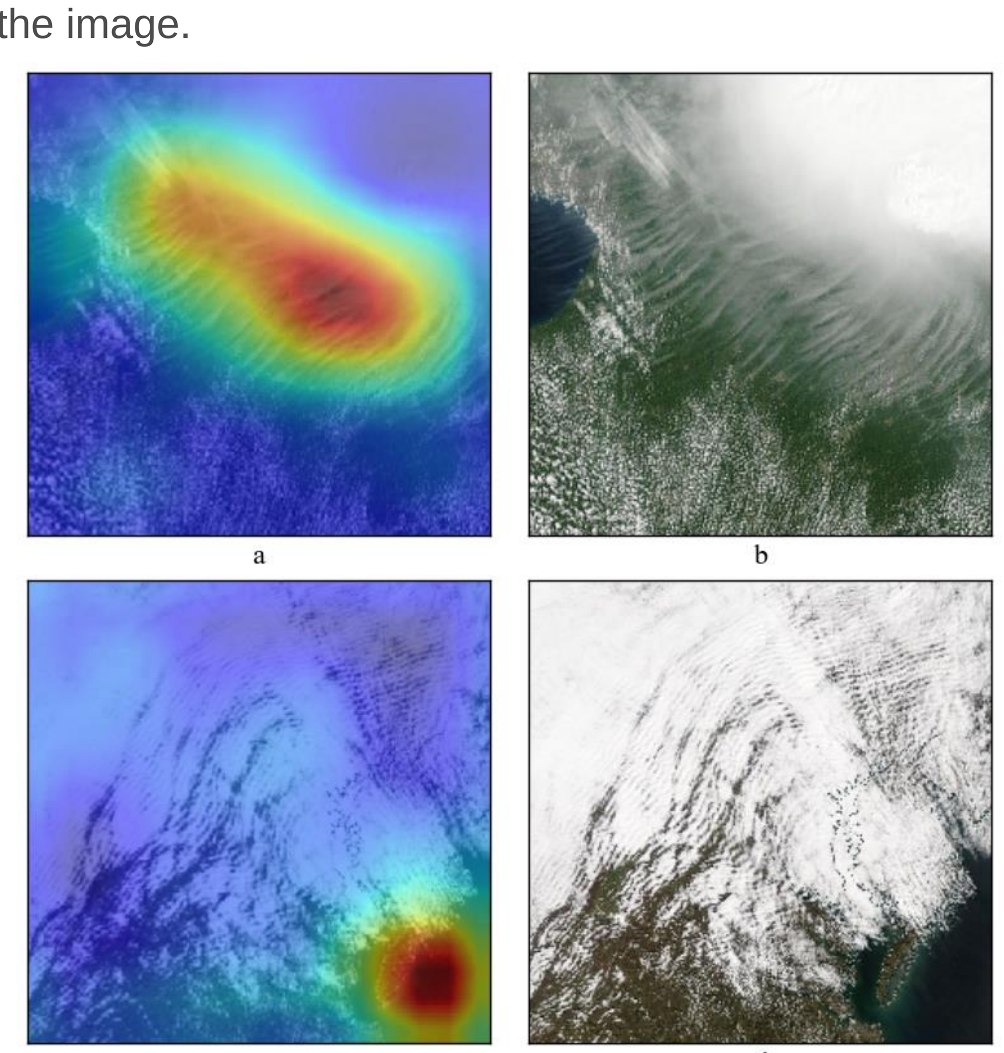
Training Results

- Test accuracy: 94.4%
- Matthews Correlation Coefficient (MCC): 0.87
- F1-Score: 0.94
- Compared results with a random forest (RF) classifier trained on the exact same data (table below)
- CNN performed better than RF classifier in all performance metrics.

	MCC	F1	Accuracy
RF	0.54	0.79	80.7%
CNN	0.87	0.94	94.4%

Class Activation Maps (CAMs)

- Highlight the feature of the image that were most important for classification
- Shows that the network is able to identify the bands within the image.

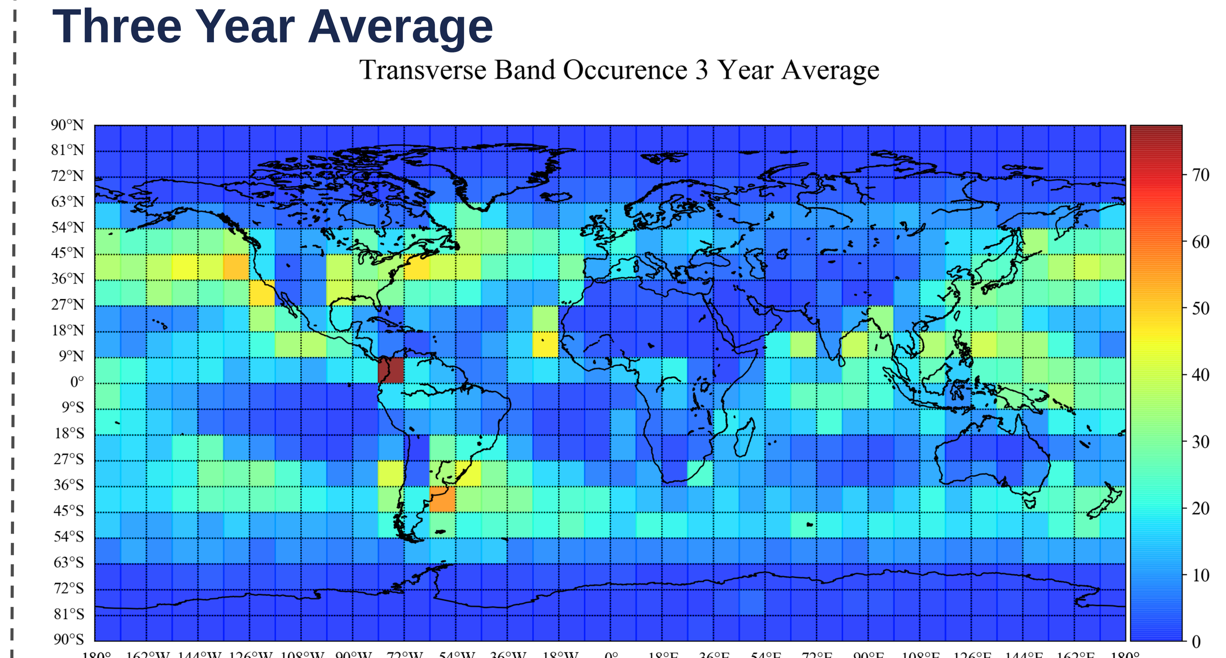


CAMs for an image with TCBs (a) and without TCBs (c). Images without the CAM are included (b and d) for perspective.

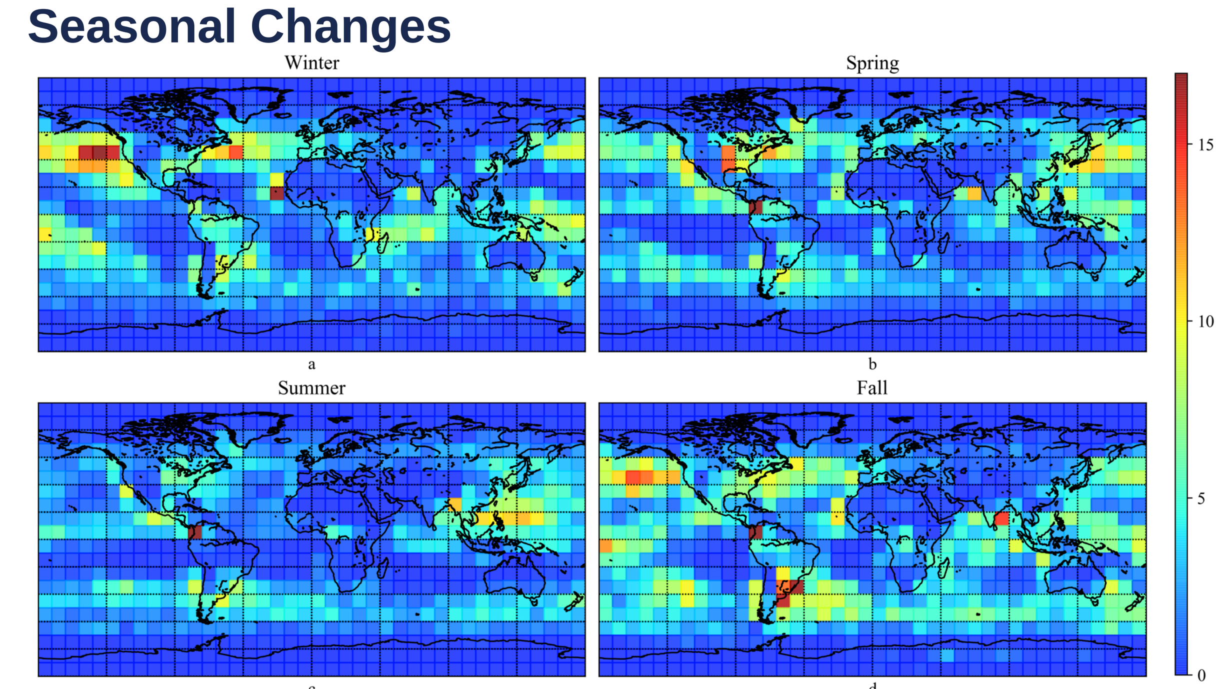
Global Climatology

The network was used to classify 3 years of MODIS RGB imagery to better understand regions where TCBs most often form.

Three Year Average

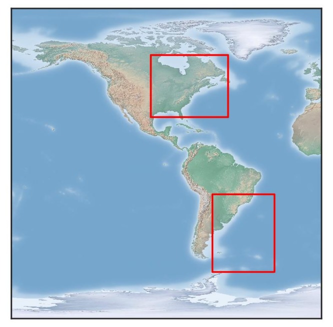


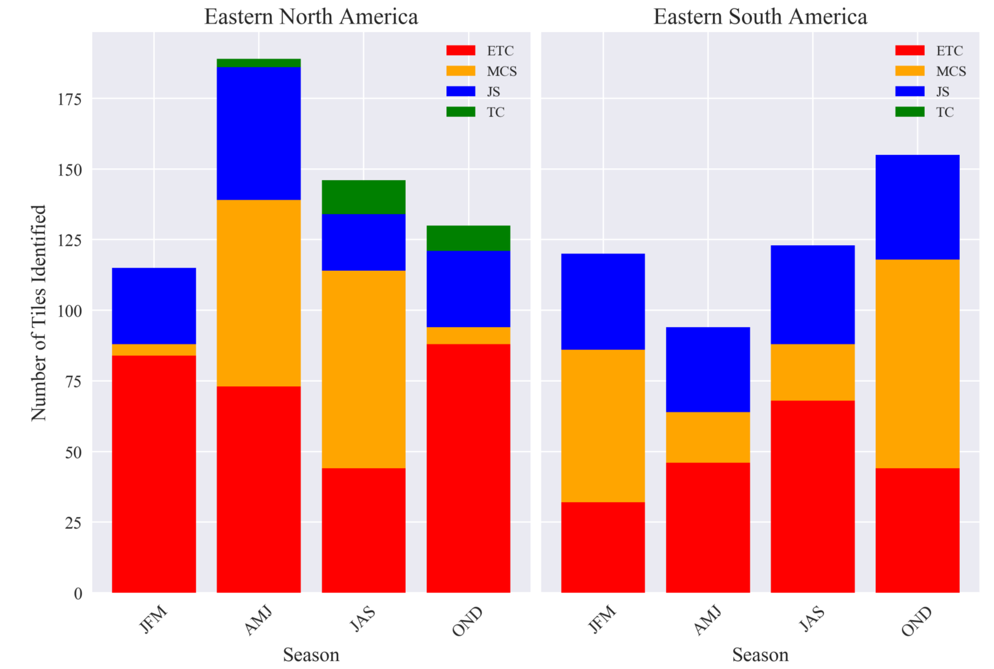
Seasonal Changes



Regional Differences

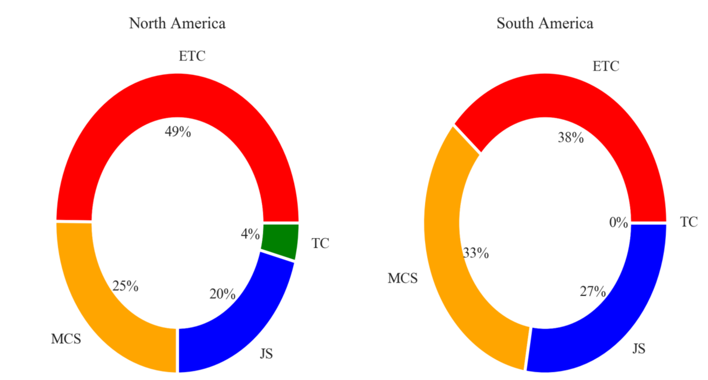
- Which parent phenomena are TCBs most often associated with?
- Focused on North America (NA) and South America (SA)





Findings

- Both regions see a maximum in TCB occurrence in spring
- NA minimum is in winter and maximum is in spring
- SA minimum is in fall and maximum in spring
- TCBs were most common with ETCs in both regions
- SA experiences TCBs associated with MCSs more often than NA
- NA had a larger number of tiles identified containing TCBs than SA (580 vs 492)



Conclusions

1. A CNN can be used to identify TCBs in RGB satellite imagery
    - CNN out-performed RF classifier trained on the same data
2. TCBs show a preference to form in regions with jets
    - Seasonal variation in TCB occurrence appears to follow the seasonal variation in jet-cores [Pena-Ortiz et al, 2013]
    - TCBs are most common in the warm months for both regions.
3. TCBs form most often in association with ETCs in both NA and SA
    - MCSs were more common in SA than in NA

References

1. Maskey, M., R. Ramachandran, and J. Miller, 2017: Deep Learning for Phenomena-based Classification of Earth Science Images. J. Appl. Remote Sens., 11, doi:10.1117/1.JRS.11.042608.
2. Simonyan, K., and A. Zisserman, 2015: Very deep convolutional networks for large-scale image recognition. *Iclr*, 1–14, doi:10.1016/j.infsof.2008.09.005.
3. Zhou, B., A. Khosla, A. Lapedriza, A. Oliva, and A. Torralba, 2015: Learning Deep Features for Discriminative Localization. *arXiv1512.04150 [cs]*, doi:10.1109/CVPR.2016.319.
4. Pena-Ortiz, C., D. Gallego, P. Ribera, P. Ordonez, and M. Del Carmen Alvarez-Castro, 2013: Observed trends in the global jet stream characteristics during the second half of the 20th century. *J. Geophys. Res. Atmos.*, **118**, 2702–2713, doi:10.1002/jgrd.50305.

Contact: jjm0022@uah.edu

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE